Varying benefits of irrigation expansion for crop production under a changing climate

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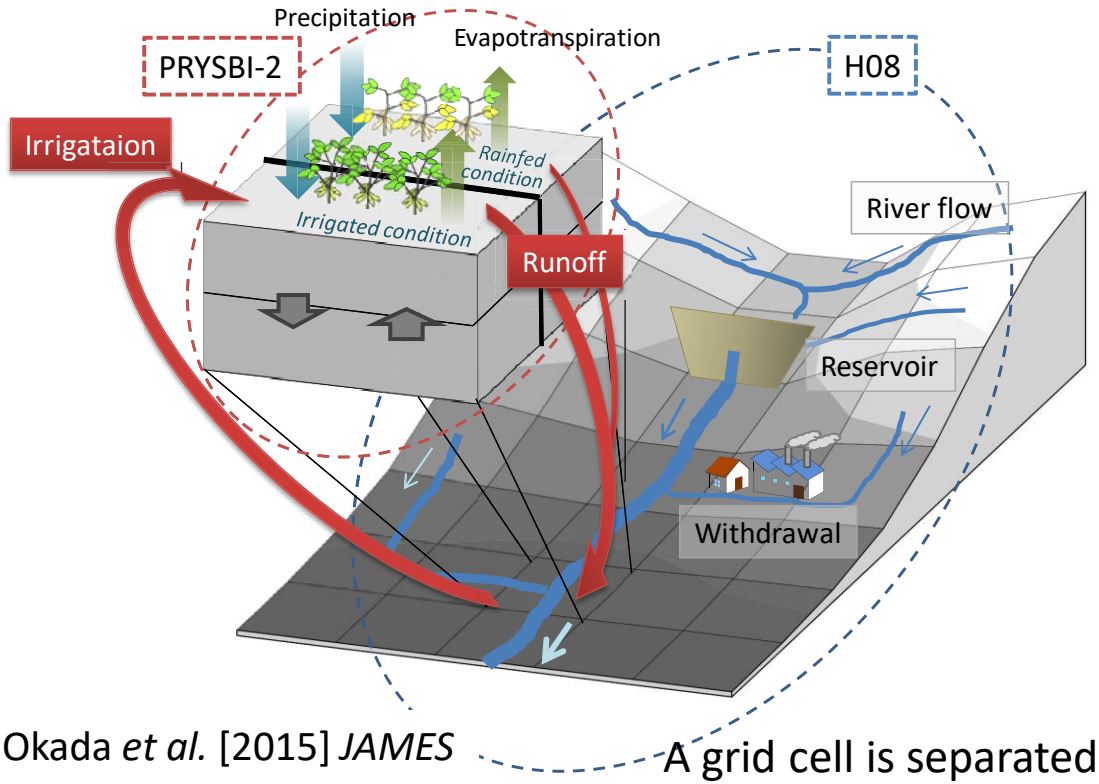
Background

- Replacing rainfed cropping systems with irrigated systems has been deemed an effective agricultural adaptation measure under climate change.

- However, few agricultural impact assessments have considered changes in the water availability because of climate change and water-use competition among crops.

- Here, we assessed future global crop production under a changing climate and expanded irrigation using the large-scale crop-river coupled model CROVER.

CROVER model



Okada *et al.* [2015] *JAMES*

- The CROVER model was developed by combining 3 components from PRYSBI-2:
  - (1) Crop growth,
  - (2) Land surface hydrology,
  - (3) Soil carbon dynamics

  and 3 components from H08:
  - (1) River routing,
  - (2) Reservoir operation,
  - (3) Anthropogenic water withdrawal.
- It operates at a 1.125-degree resolution at a daily time step.

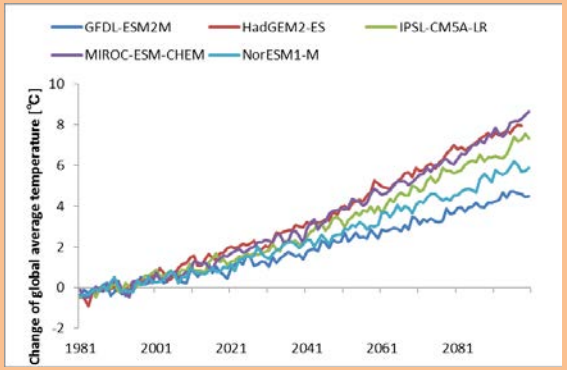
A grid cell is separated into 11 land-use categories
- -5 crops (maize, rice, soybean, spring wheat, winter wheat)
- - 2 conditions (irrigated, rainfed)
- - 1 vegetation

- Such the crop model that can simulate crop growth considering dynamic terrestrial water cycling under changing climate and land use, and varying water availability are LPJml and CROVER only.

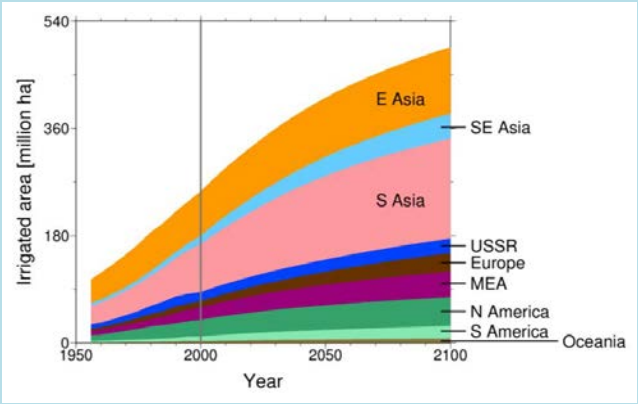
Methods

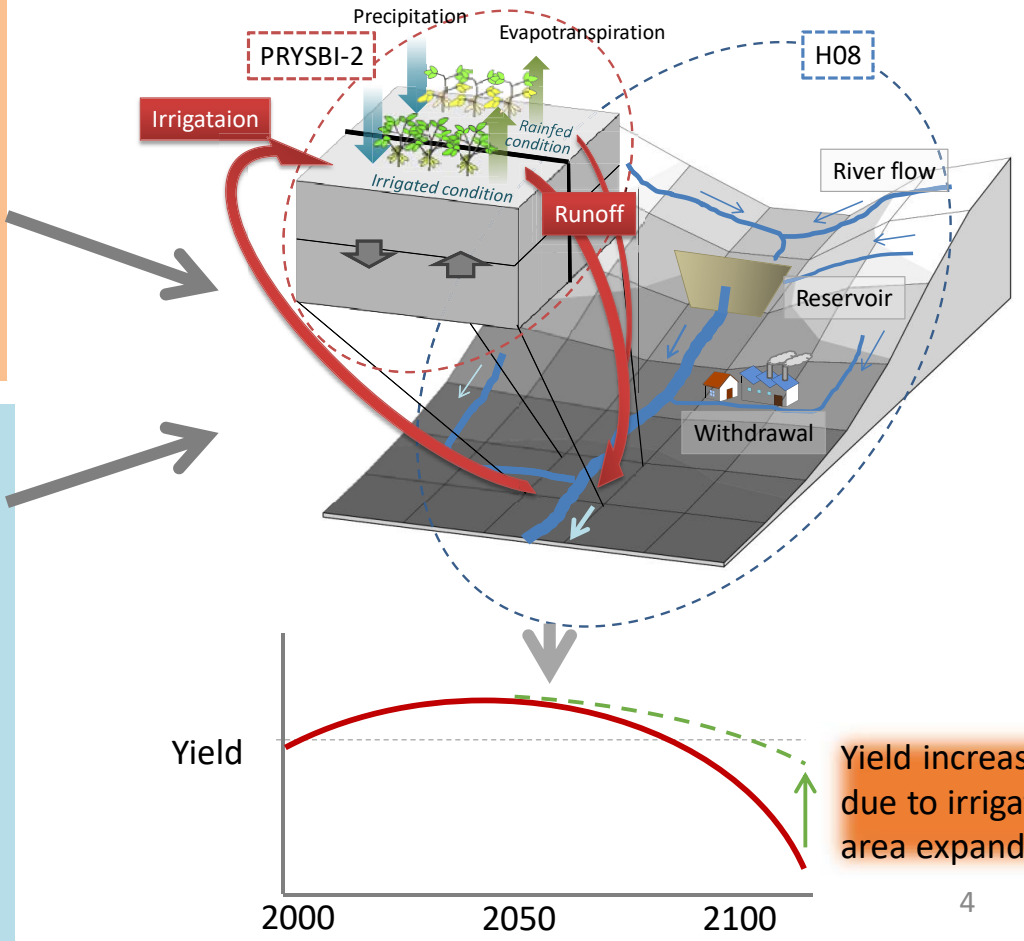
- This study applied two types of future scenarios to the CROVER model.
- The study assessed the potential effects of expanding irrigation on crop production within the context of climate change.

Climate change scenario [Iizumi et al. 2017]



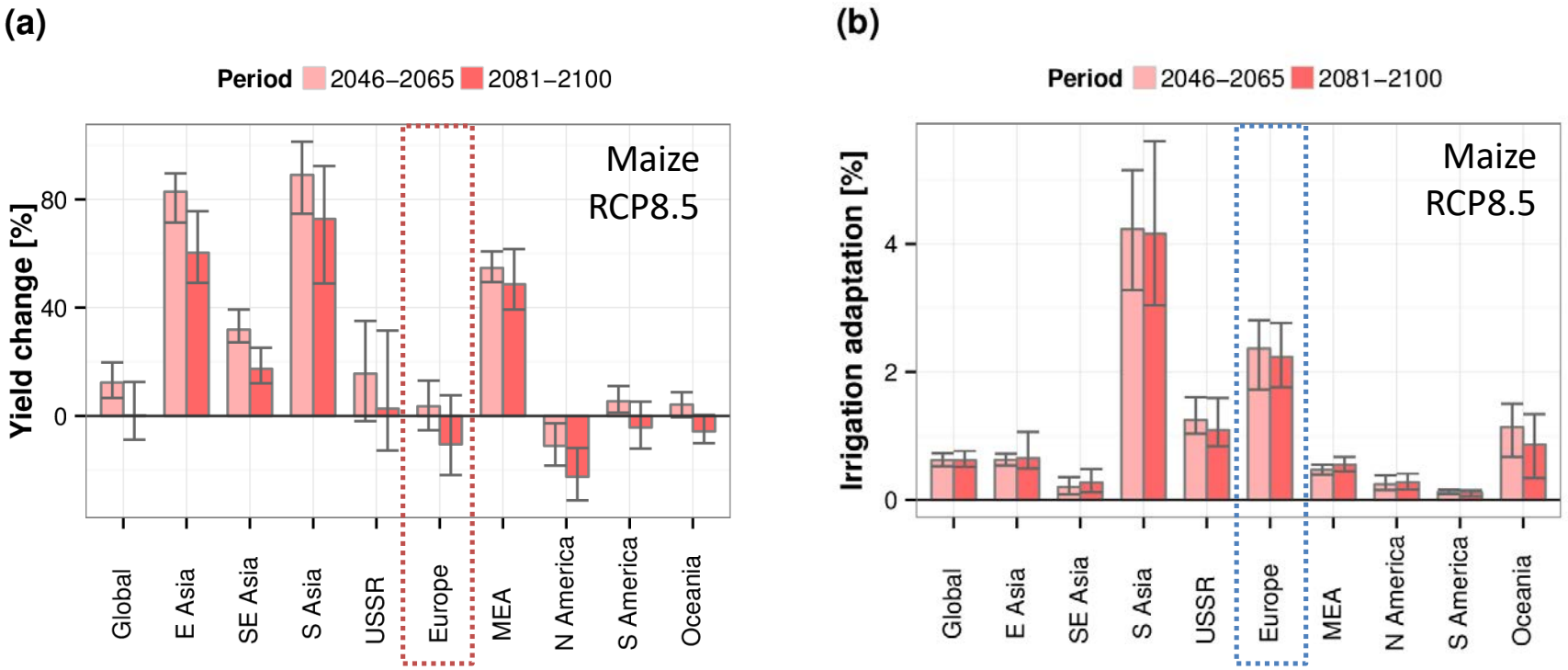
Irrigation area expansion scenario (developed by this study)





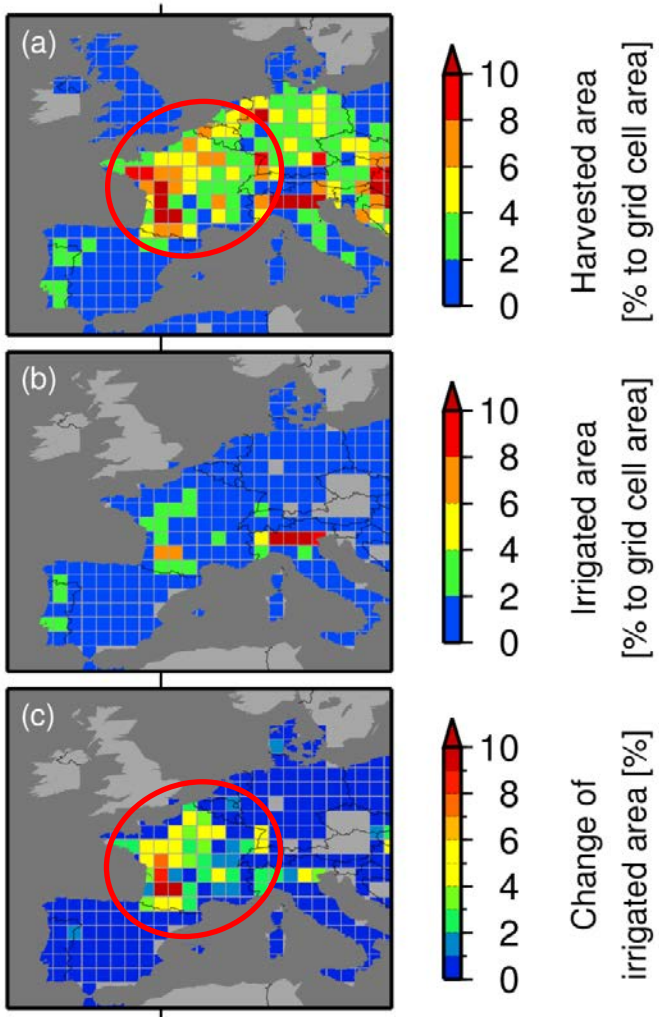
Case 1.
Expanding irrigation leads to increased production

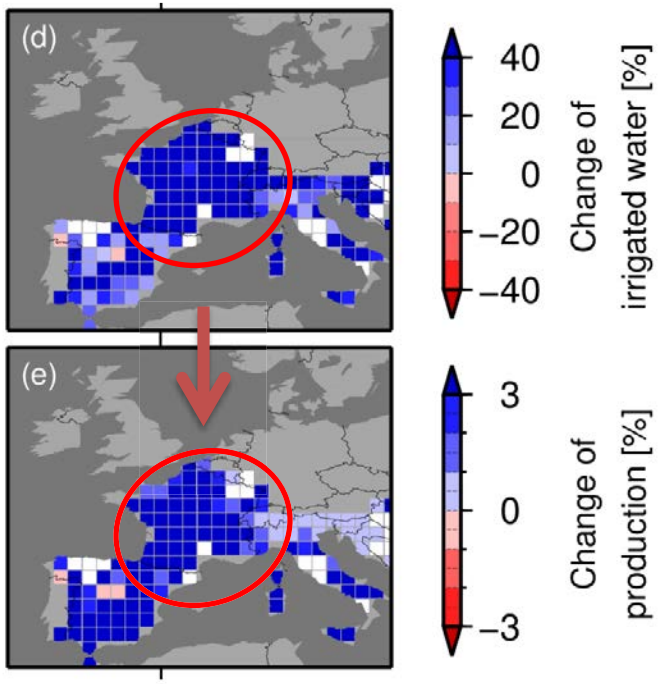
- **Yield change**: At the end of this century, the yield decrease in Europe.
- **Irrigation adaptation effect**: The yield decrease was effectively mitigated by the irrigation expansion in Europe.



Case 1.
Expanding irrigation leads to increased production

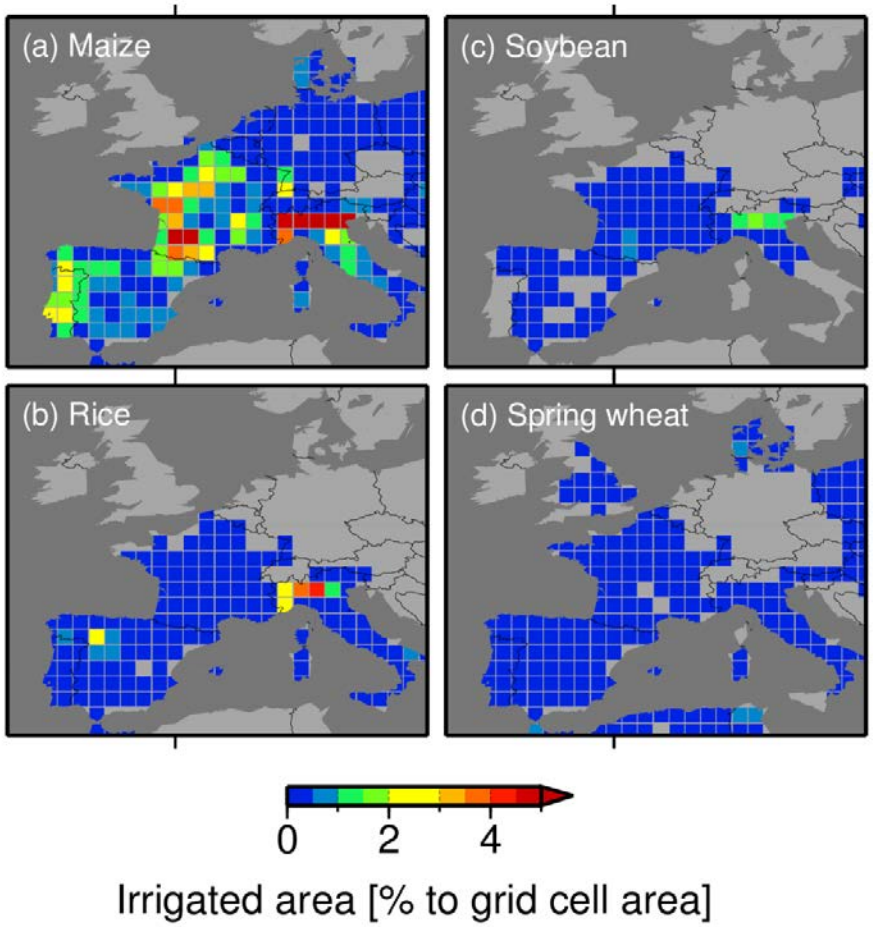
- Irrigated water was projected to increase around France with the expanding irrigated area, brought increase in maize production.





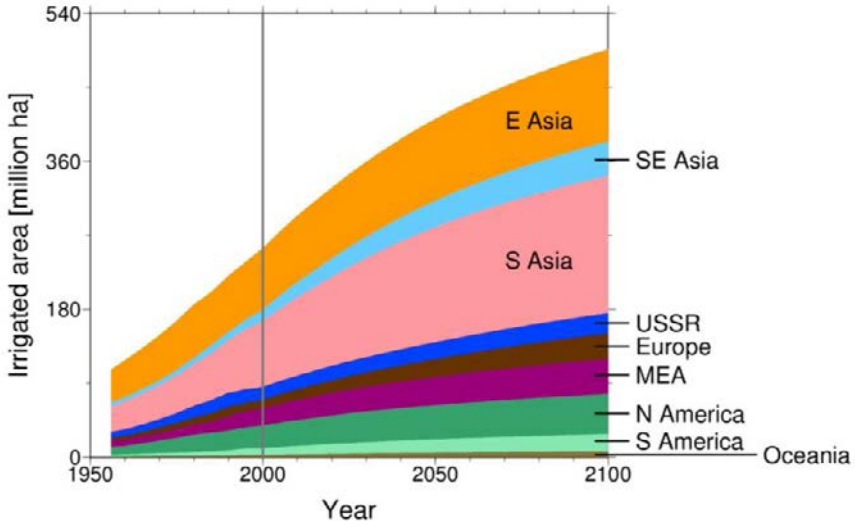
Case 1.
Expanding irrigation leads to increased production

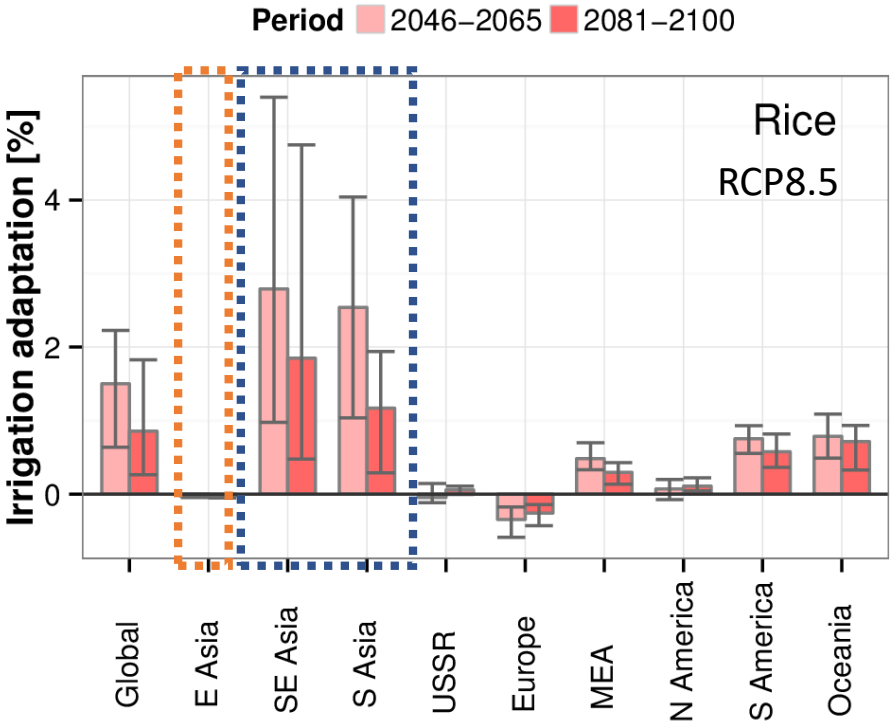
- Irrigated areas of the other crops than maize are little.
- Water use for irrigation on maize field hardly compete with those on the other crops.



Case 2.
Expanding irrigation does not lead to increased production

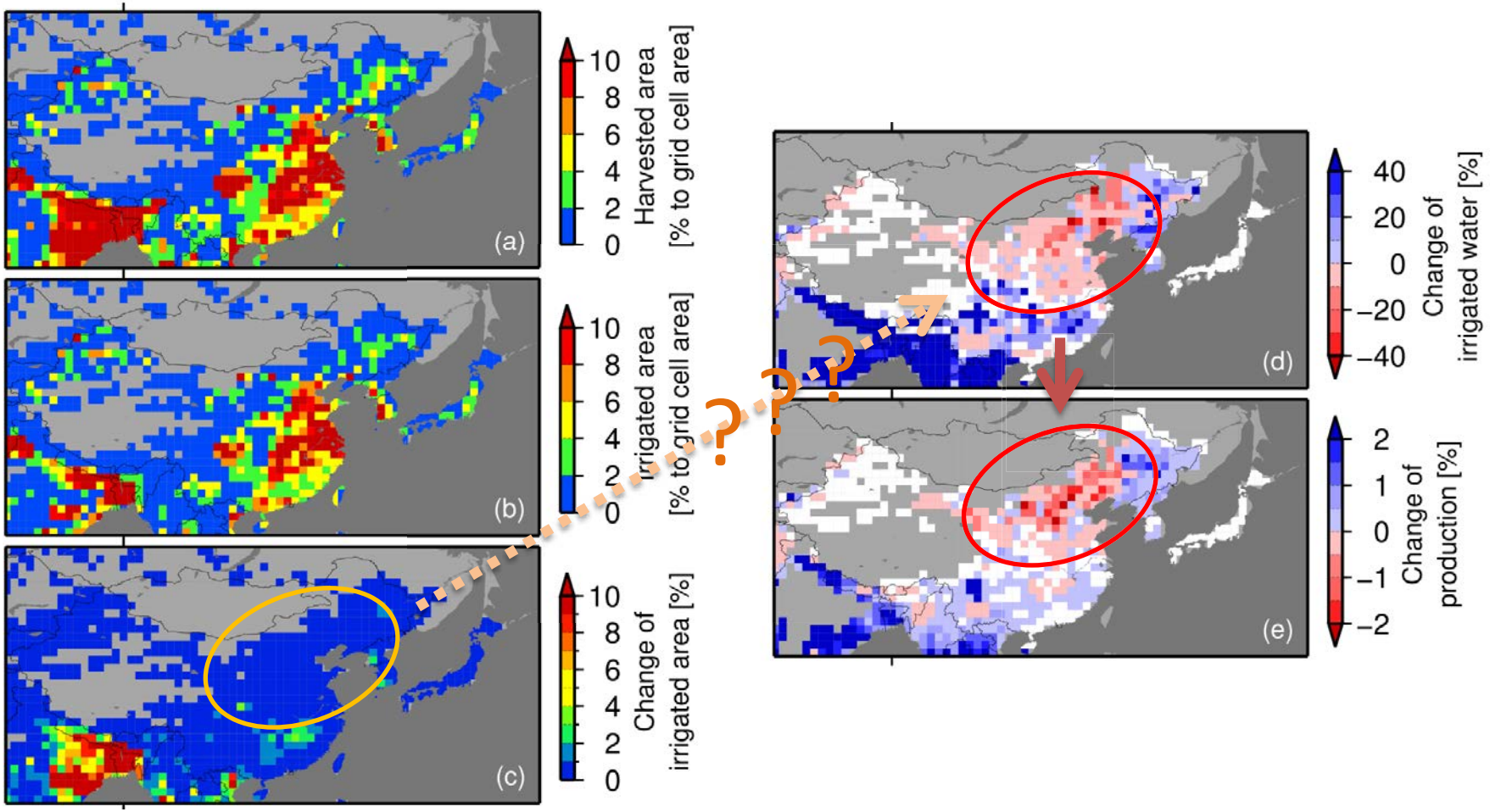
- **Southeast and South Asia:** the rice yield increased because of the irrigation expansion.
- **East Asia:** the effect of expanding irrigation is negligibly small, even though the irrigated area expands.





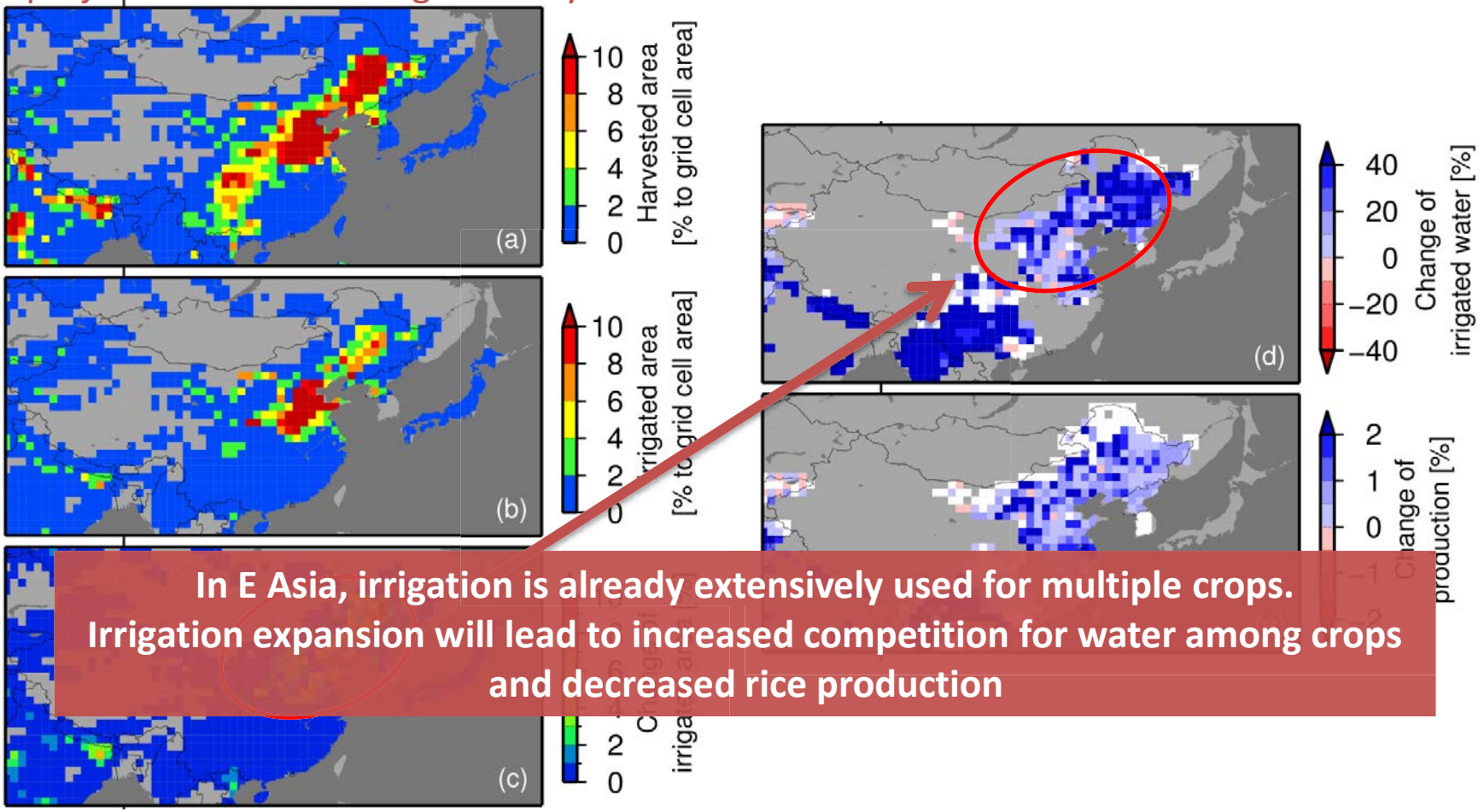
Case 2.
Expanding irrigation does not lead to increased production

- Irrigated water was projected to decrease at the north part of China, although the irrigated area expands.
- It brought **decrease in rice production**.



Case 2.
Expanding irrigation does not lead to increased production

- At the north part of China, the irrigated area of maize was estimated notable expansion.
- With the notable expanding irrigated area, the applied water to the maize field was projected to increase significantly.

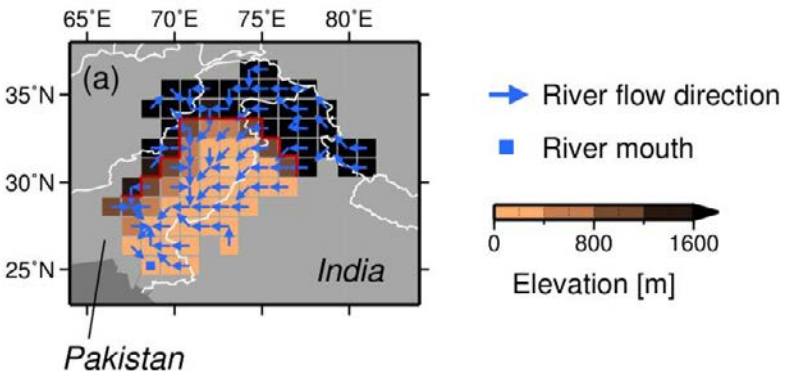


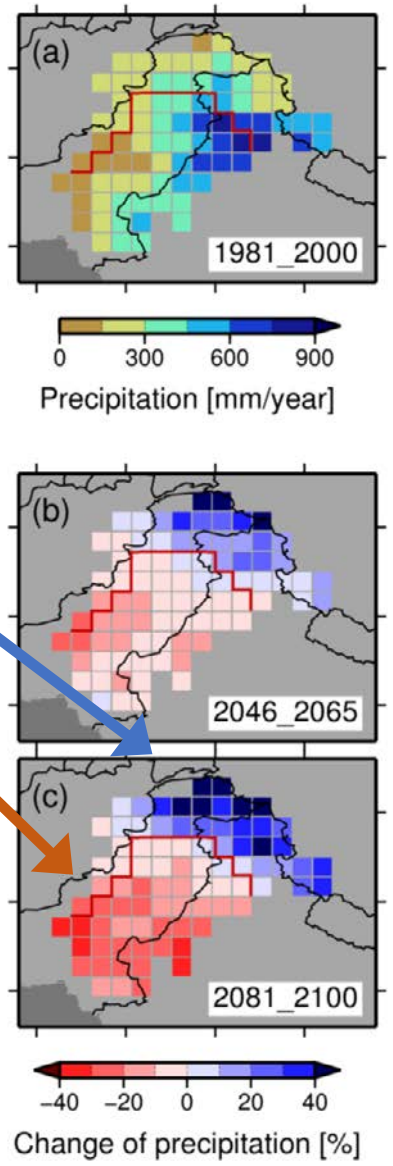
In E Asia, irrigation is already extensively used for multiple crops. Irrigation expansion will lead to increased competition for water among crops and decreased rice production

Case 3. Geographical patterns of projected precipitation change influence the benefits of irrigation expansion

- In this case study, we used a single GCM (GFDL-ESM2M) to simulate contrasting precipitation changes between the higher and lower areas of a watershed.

- The GCM shows that;
  - precipitation increases in the higher watershed area,
  - precipitation decreases in the lower watershed area.



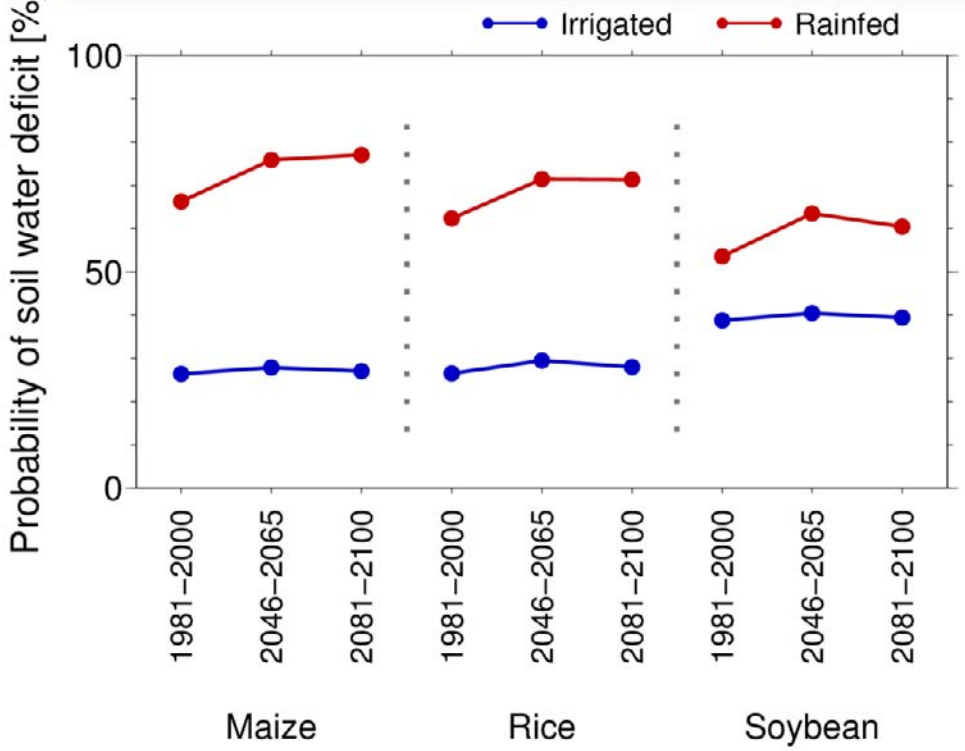


Case 3. Geographical patterns of projected precipitation change influence the benefits of irrigation expansion

Rainfed: water deficit is anticipated to increase due to the decreased precipitation in the plain area.

Irrigated: water deficit changes little because the increased precipitation in the mountainous areas of the watershed provides additional water resources.

Change in probability of occurrence of soil water deficit in the plain area over the Indus River watershed



Conclusion

- Our assessment using a crop-river coupled model reveals three interesting cases;
  - ✓ that expanding irrigation can be a useful adaptation measure in some areas where a single or a few major crops are grown under irrigated conditions (e.g., Europe),
  - ✓ but that irrigation expansion produces only limited crop production increases in areas where irrigation is already extensively used for multiple crops (e.g., East Asia) due to competitive water use among crops.
  - ✓ and that increased precipitation in the higher mountainous areas of a watershed can reduce yield losses caused by precipitation decreases in lower watershed areas (e.g., the Indus River watershed).

- These findings emphasize the importance of considering intercrop water use competition and the associated changes in the water availability in addition to future precipitation changes when planning irrigation expansion to adapt to climate change.

Thank you for your attention